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# THE EFFICACY OF STRATEGY IN HIGHER EDUCATION - A METHODOLOGY

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## **Abstract**

All research intensive universities (RIU's) want to expand their scope of operations. Research performance is a key driver of institutional reputation which underpins a university's ability to generate revenues from all sources. Achieving an accelerating rate of growth of the virtuous cycle, in which increasing research performance enhances institutional reputation which, in turn, facilitates increasing research performance, is the desired objective of RIU's. This shared objective is contributing to an intensification of the competition for research funds.

Successfully competing for research funds depends on realizing an increasing share of the federally financed research funding that is available to academic institutions. To this end, RIU's are using strategic processes with varying degrees of intensity and formality in an effort to achieve their objectives. The question arises as to whether these strategies produce desirable outcomes. That is, are some expressions of strategy more closely associated with an increased share of federally financed research funding than others?

This methodology provides insight into this question by presenting a model that exposes the strategic emphases of individual RIU's which are correlated with the changes in the shares of federally financed research funding actually realized by the institutions. Using this method, the relationship between strategy and institutional performance is observable which can be used to inform the process of strategy formation.

## Introduction

All research-intensive universities (RIU) want to create the virtuous cycle which, depending on their degree of success, constitutes the rate of growth of their institution. Burton Clark (1992) describes a process whereby RIU's strive to create the best conditions for research and recruit the best students and the most prestigious, accomplished, or promising faculty that is within their capabilities. These factors enhance research performance which, over the course of time, results in strengthening an institution's reputation (Lang, 2004; Geiger, 2004). In turn, a prominent reputation attracts more of the best students and researchers who generate greater research revenue for their institution. In this way, increasing research performance leads to a strengthened reputation and, if reputation is the driver of growth, then achieving growth is founded in successfully competing for research funds. This is not a static process. If the virtuous cycle is not being continually fed, an institution's rate of growth will be eroded by a collective attack that is neither malicious nor coordinated, but represents the effort of each RIU to achieve the same end. This phenomenon underlies the proposition that competition for research funding is intensifying among RIU's. The use of strategy and strategic processes are widely used in the belief that it will enhance competitive effectiveness as affirmed by Keller's (1983) remark that, "any organization with competitors, with aspirations to greatness, or with threats of decline has come to feel the need for a strategy." (p. 75) Many similar statements have followed.

This paper details the methodology used to enhance the understanding of the efficacy of strategy in the competition for research funding among RIU's. In order to conduct the study, research data, accessed from the National Science Foundation (NSF), were collected for 39 RIU's and for the national market of the United States. The study used the data to compare differences in the research priorities of individual RIU's and to determine whether these differences, which are reflective of underlying strategies, have any relationship to the changes in the size of the shares of the market they held during the decade ending in 2000. In this way, it may be possible to relate certain manifestations of strategy with market outcomes.

The first contribution this paper can make relates to the measurement of strategic performance. There is currently no universally accepted or used indicator to gauge strategic performance in the higher education research market in the United States (Feller, 2000; Hauger, 2000). Benchmarking

is the method most widely used by RIU's to measure strategic success which is, in general, a process of selecting a group of institutions that are determined to be comparable for the stated purpose and then calculating performance against the peer group. Inevitably, selecting the group involves subjective judgments (Lang, 2000) made by those that are likely to be accountable for the institution's relative performance. The inherent conflict, real or imagined, increases the probability that the information produced will be less credible to external accountability agents. It should be quickly added that this remark is not intended to suggest that benchmarking is not an important, valuable, and evolving tool. Pennsylvania State University (Penn State, 2004), which is among the most transparent reporters of research activity, uses NSF federally financed science and engineering field categorizations to produce currency and ordinal rankings in what is essentially a peer group for each of its areas of research. Penn State, and similar reporters, has advanced the practice of strategic outcome measurement of research beyond a more subjective peer group method in that it ranks itself against the entire population of institutions that outperform it in each of the NSF fields in which it is strategically interested. This method enables a quantitative ranking in which changes in the institution's relative market position can be tracked over time. Strategic success will be reflected in a higher ranking or fewer outperforming institutions. In addition, Penn State compares its total and federally financed research performance using this method.

Glasgow University (GU a., 2001), which is one of the more sophisticated reporters in the United Kingdom, uses a method that, in many ways, is similar to Penn State's in that it ranks itself in each Unit of Assessment (RAE, 2001) using an ordinal ranking. In addition to ordinals, GU uses percentiles to describe its position relative to all institutions that submitted work in each Unit of Assessment; in effect, generating a national positioning in each market segment in which it operates. Interestingly, GU appears less interested in a national ranking of its total or federally financed research performance than its RIU counterparts (GU b., 2001). The major factor that distinguishes GU from RIU rankings is that RIU's use currency as the basic unit of comparison whereas GU follows RAE scores to underwrite its ranking system. Since the RAE scoring system is based on the peer review of scholarly production (such as publication) it is innately judgmental (Braxton, and Boyer, 1986). In this sense, the benefit of using currency as the basic unit underpinning strategic performance rankings is that, despite its reductionist nature, it is highly objective

and, among RIU's, nearly universally used.

The methodologies described above recognize the notion that measuring strategic performance requires comparisons with the performance of competitors. A successful strategic process will advance an enterprise's rankings, whether expressed as an ordinal, a percentile, or in currency values. In the instance of benchmarking using currency values, the most common and current form of measuring strategic research performance among RIU's, the question must be asked as to the performance of the peer group in relation to the total market. If a university's ranking is rising among its peers and the group's collective performance is simultaneously rising versus the market, than that university is experiencing real growth. However, if the peer group is declining versus the market, even a university that is rising within its group may be experiencing real decline. Over the long term, the later scenario can have a surprisingly adverse impact, much as inflation deflates the purchasing power of money. To overcome this problem, an indicator that relates institutional performance to the market in an objective, quantitative, easily understood, easily derived, and universally applicable manner is required. To this end, this paper proposes the use of the change in share of the research market as the indicator used to measure the strategic performance of RIU's.

Strategy can be defined as a pattern in a stream of resource allocations (Mintzberg, 1972), and in limited resource environments such as exists in the academic research market, this forces choices between investing to enhance the capacity of one research portfolio component to a greater extent, or at the expense of others. The reasons behind these allocations is strategy; the actual allocation is the activation of that strategy. In other words, strategy is not the value of resources allocated to a particular research portfolio component; strategy is the value of the allocation in relation to allocations made to other research portfolio components or other areas in the university requiring resources. Strategy is about choices (Porter, 1996; Ansoff, 1988). Given an appropriate lag time, investments in research capacity generally result in increased research performance. As such, it can be expected that a research portfolio component that has continually received the largest share of investment in research capacity will eventually achieve a rate of growth in research performance that outstrips other components in the portfolio. At a certain point, this component is likely to become the largest component in a university's research portfolio. This situation is most apparent in universities

that conduct research in the medical sciences. Observing relative changes in the research performance of portfolio components of RIU's can be used as a mechanism to track the consequences of strategic decisions.

If strategic input is the relative size and change in size of investments in capacity, just as the strategic input of a mutual fund is the array of assets it decides to hold over time, then the strategic success of these decisions is an institution's research performance relative to the market. If a university has made the right investments in research capacity, then, *ceteris paribus*, it will experience a rate of growth in research performance that is greater than the rate of growth of the market. In other words, its share of the market will increase. Strategy then, is the search for the balance of portfolio components that produces the desired outcome which, in the case of the research market, is the fastest rate of growth in the share of the market.

The national research market that is used in this study, as defined below, is "Federally financed R&D expenditures at universities and colleges," as reported by the NSF (NSF e.). This selection was made based on each of the four major academic research funding components, namely, the federal government, internally allocated resources, industry, and state governments, meeting all four of the following conditions, presented here in brief:

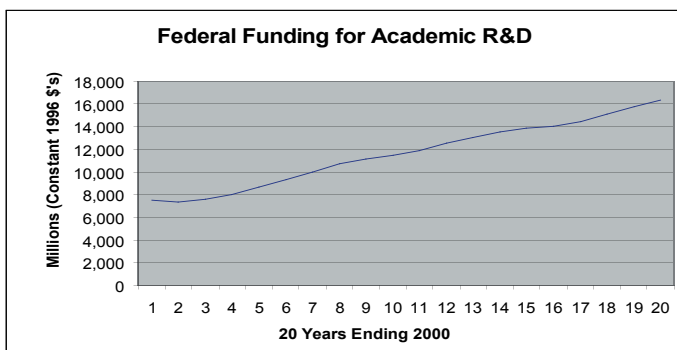
The first condition relates to the degree of plurality in a system of research funding to the extent that it enables any researcher in any institution the ability to submit proposals for support through a national inter-institutional bidding process. Such a system promotes the widest possible range of exploration while creating intense competition, a combination of attributes that strengthens the system as a whole (Ben-David, 1972; Birnbaum, 1983). In addition, David Dill's 1997 article succinctly describes how such a system protects the social welfare by, for example, establishing an informed market that fosters economic efficiency through controlled prices, increased rigor, discipline, and quality in the conception, preparation, execution, and management of research, and by helping ensure that the range and methods of research are in the public interest. The national open bidding condition is a market attribute that serves to strengthen the system by forcing each participant to continually improve. It most closely describes that segment of research funding that is provided by the federal government. Internally allocated resources are a source of research funding that does not meet the open bidding condition since these funds are rarely

available to other than the home institution. Likewise, state sponsored research funds are almost never available to universities outside of the home state.

Industry funding is not a monolithic source of funds. A significant proportion of industry sponsored research is conducted by the largest companies close to their headquarters (Statistics Canada, 2000). The proximity factor disqualifies most RIU's from bidding on most industry sponsored contracts. In addition, industry sponsored research is almost entirely applied in nature (Etzkowitz, Webster, and Healey, 1998) and most faculty are not engaged in research of this type (NSF e.). As such, the proportion of industry sponsored research that is open to national bidding is likely a small portion of total industry sponsored research funding which, in turn, only represented seven percent of the entire value of research performed by academic institutions in 1996 (Jankowski, 1999). As a consequence, industry funded research has been deemed not to meet the open market condition.

A commitment to long term research is foundational to RIU's and the second condition relates to the risk that universities have to take when they make investments in the capacity that supports their research, such as tenured faculty or fixed infrastructure, that can take decades to yield a full return. Long term market predictability significantly reduces the risk of making these investments since the offsetting revenue can be reasonably estimated. With systematic risk substantially mitigated, the major challenge for RIU's becomes the more controllable operational risk which relates to the set of actions and decisions that are made in an effort to earn a share of an existing market.

Federal financing of university research represents a very predictable and dependable source of research funding as demonstrated by the smoothness and relatively constantly sloped line in the figure below.



Source: NSF f.

Funding from industry must be considered as volatile if for no other reason than businesses that supply the funds are themselves volatile. The stock markets exemplify this where corporate decisions are made from quarter to quarter and long term planning is only valid as long as the short term results support the plan. In addition, businesses are not likely to undertake research projects whose duration spans more than a couple of years (Feller, and Roessner, 1995) and, as such, this funding source does not meet the second condition. While the foci of state sponsored research funding can change abruptly, most often when new administrations come to power, these changes more often reflect the relatively slow evolution of local economies. For this reason, it can be argued that state sponsored research does meet the second condition. Finally, self-financed research, even with internal competitive pressures (Massy, and Zemsky, 1994), should be regarded as meeting the second condition.

The third condition asks the question of what proportion of an enterprise's revenue stream constitutes a strategic imperative. One method of approaching this issue is to speculate what might happen in a disaster scenario. That is, if a portion of an enterprise's revenue stopped flowing, what would be the consequences?

In 2000, research funding from industry was 6.9 percent of all research performed by RIU's (NSF g.). These funds are dispersed across a range of disciplines although there is a degree of concentration in the life sciences fields. It is also notable that industrial sponsored research comprised a proportional maximum of 30.8 percent of Duke University's research performance and as little as 0.9 percent of the University of Chicago's in 2000. While this range makes it difficult to generalize, it can be suggested that, in a disaster scenario, an RIU losing not more than 10 percent of its total research income would not have to make survival type re-alignments to its total faculty complement or overhead structures. 32 of the 39 RIU's meet this criterion. This statement is a reasonable assumption even in cases where industry sponsored research comprises more than 10 percent of research performance in several departments within an RIU. A similar scenario can be described for state sponsored research which comprised eight percent of total research expenditures in academic institutions in 1996 (Jankowski, 1999). As a consequence, it can be stated with a reasonable degree of confidence that neither of these two funding sources meets condition three. However, at an average of 67.8 percent of the RIU's 2000 research performance, the same cannot be said for federally



financed research expenditures. Indeed, if not for federal research funding, there would be no RIU's as we know them.

The fourth condition is an attempt to determine which research revenue streams contribute more directly and to the greatest extent to an RIU's virtuous cycle. In other words, if one research revenue stream helps establish an RIU's national and international reputation to a greater extent than other streams than it should be considered as more strategically important. Given that state sponsored and internally allocated research streams have already been disqualified from inclusion in the research market they will not be considered at this point. The determination of whether federally financed or industrial sponsored research revenue streams meet condition four relies on the criterion of whether the research is peer adjudicated because this is the common denominator upon which international reputational comparisons are made (Liu, N.C., and Cheng, Y., 2005; O'Leary, J., 2004; The Center, 2003). Simply put, industry sponsored research does not meet this condition and federally sponsored research, by virtue of the method used to award funding, is peer adjudicated.

Since the federally financed research component of research income meets all four conditions, it was chosen as the market for this study. It should be clarified that this argument is not suggesting that research income is not important from all sources or that investments in capacity do not enable competing for multiple income streams, it is only meant to describe a market comprised of a buyer and sellers that is identifiable, for which analytic data are available, and which can be reasonably argued to be a proxy for understanding the research strategies of RIU's.

The second contribution this paper hopes to make is the introduction of several performance indicators that, when taken together, form the backbone of the methodology herein used. Of special note are indicators entitled the Institutional Strategic Indicator (ISI) and the Market Strategic Indicator (MSI). Both of these indicators rely on portfolio theories (Markowitz, 1990; Naylor, and Tapon, 1982; Henderson, 1973) that are interpreted to support the following statements: In a multi-unit enterprise, the largest and fastest growing units or portfolio components are of greater strategic importance to the enterprise than small contracting components. Similarly, large fast growing market segments provide greater strategic opportunities, *ceteris paribus*, than small declining market segments. Lastly, enterprises want as many large fast growing portfolio

components in market segments that are also large and fast growing as possible. RIU's that have research components that have achieved the later status will maximize their return on investment which, in the research market, is the generation of a greater value of research performed, as measured in real terms against the market as a whole. In other words, return on investment in the research market is measured by changes in market share. The use of ISI and MSI in the methodology described in this paper is intended to assist strategists that operate in the research market to more accurately locate the market positions of their institutions and that of their competitors.

The third contribution this study makes is that, if it is determined that a certain strategy is more closely associated with market success than other strategies, than RIU's will want to adopt such a strategy. Perhaps more to the point, if any readers of this paper are in a position to influence research strategy, and who are convinced that the methodology presented herein is sound, and that the preliminary conclusions reached reasonably follow from the data, than research strategic processes in higher education will be better focussed.

The fourth significant contribution that this study might make is to add a special case to the extensive body of research that has been done on the efficacy of strategy. This study is a special case because it overcomes one of the most common criticisms of research published in this field which is the difficulty in defining industry boundaries (Barney, J., 2001; Boyd, B., 1991). The national market for federally financed research is a closed system in that there is only one buyer and a fixed number of identifiable sellers whose activities can be effectively monitored through the reporting function of the NSF. In addition, it is a complex and highly competitive market which makes its study non-trivial and of possible interest to strategists and economists alike.

## Definitions

### National Market:

The national market is highly fragmented (Geiger, R., and Feller, I., 1998) and behaves, more than other forms, as a monopolistically competitive market. In this market type, Michael Porter's (1985) differentiation strategy is the only way to achieve market success which, given that RIU's are non-profit organizations, can only be measured by observing changes in the market shares that occur among competitors. In this study, the national market is defined

as the total of all federally financed R&D expenditures in colleges and universities, as reported by the colleges and universities that received those funds and regardless of which federal agency provided those funds. As previously described, even though universities receive research funding from other sources, for the purposes of this study these sources have been excluded. In addition, and for the reasons provided below, amounts from all NSF fields entitled “Other, nec,” and from “Other Sciences, nec,” and “Bioengineering/biomedical,” (NSF a.) were excluded.

**1990a:** 1990a is the arithmetic mean of data from the years 1989, 1990, and 1991 inclusive. In later specified circumstances 1990a is the arithmetic mean from the years 1988 through 1992 inclusive. The purpose for using an average of years is to mitigate the risk that 1990 was an anomaly. For greater certainty, when the term ‘1990’ is hereafter used, it refers to that actual year.

**2000a:** 2000a is the arithmetic mean of data from the years 1999, 2000, and 2001 inclusive. In later specified circumstances 2000a is the arithmetic mean from the years 1998 through 2002 inclusive. As in the case of 1990a, the purpose for using an average of years is to mitigate the risk that 2000 was an anomaly. For greater certainty, when the term ‘2000’ is hereafter used, it refers to that actual year.

**Field:** A field is a category of research as defined by the NSF. For example, Physics is a field of research that is defined to include, “Physics as well as Acoustics, Atomic/Molecular, Chemical, Condensed Matter, Elementary Particles, Nuclear Structure, Optics, Plasma, and Theoretical/Mathematical Physics.”(NSF b.) There are 21 fields in this study as listed on Figure A. A field may also be referred to as a research category or a portfolio component or, in the case of the national market, as a market segment or a market.

**Currency:** Since this study compares percentage changes in the relative sizes of fields and market shares, the effect of currency inflation does not impact the results and, as a consequence, the decision was made to present all currency amounts in nominal United States dollars. For greater certainty, the model was run for the national market using constant 1996 dollars and, while the percentage measurements were smaller then when using nominal dollars, the results were identical.

**RIU:** An RIU is a university that was a member of the Association of American Universities (AAU) from 1988 to 2002 inclusive, and which was classified by the NSF as

one of the top 100 recipients of federal research funding from 1988 to 2002 inclusive, and which was categorized by the Carnegie Foundation as a Research University I in its 1987 and 1994 surveys and as a Doctoral/Research University-Extensive in its 2000 survey. The final filter used to define an RIU relates to the consistency of the data that each RIU reported in the annual NSF surveys. Institutions which otherwise qualify were subjected to a Ratio Variance test and were excluded from the study if the ratios of their Total Reported (the sum of all expenditures categorized into fields) to Total Actual (the total federally financed R&D expenditures reported) changed by more than plus or minus 12.5 percent between 1990a and 2000a. The decision to use this cut off point was based on the existence of a gap in the ratios from slightly more than 10 percent, to the next institution at nearly 20 percent. The reason for excluding RIU’s using this method was that large ratios indicate inconsistent reporting in one or more fields which could, in turn, affect the results of this study. The list of RIU’s can be found on Appendix A.

**x-axis:** On a two dimensional plain, the x-axis represents the values on the horizontal dimension.

**y-axis:** On a two dimensional plain, the y-axis represents the values on the vertical dimension.

**NS:** The Equalized Value for Percent of National Share (NS) is an indicator that corresponds to the equalized values for the proportion that each field represented of the national market in 2000a. The first step in generating NS for a field is to determine the percentage that each field represented of the national market in 2000a. For example, in 2000a Mathematics was 1.41 percent of the \$16.06 billion national market. This data can be seen in the column entitled ‘2000a Percent of National Spending’ on Figure B. Since NS comprises one of two equal parts of MSI, an indicator defined below, all values of ‘2000a Percent of National Spending’ were adjusted by the factor that equated the largest value to one. In the national market, Medical had the largest share in 2000a at 35.32 percent and this value was used as the denominator for all values of ‘2000a Percent of National Spending’. For example, Astronomy was 1.59 percent of the national market in 2000a. When divided by 35.32, the value of NS for Astronomy equaled 0.0449. NS relies on the concept that the greater the proportion that a portfolio component represents of an organization’s total portfolio, the greater is its strategic importance. NS ranks 2000a federally financed R&D expenditures by field in proportion to the

national market.

**ΔNS:** The Equalized Value for Percent Change in Share of National Spending (ΔNS) represents the equalized values for the change that occurred in the proportion that each field represented of the national market between 1990a and 2000a. The first step in determining ΔNS is to find the percentage change in ‘2000a Percent of National Spending’ from ‘1990a Percent of National Spending’. For example, Civil Engineering was 1.32 percent of the national market in 1990a and 1.50 percent in 2000a which means that its share grew by 13.49 percent during the period. (1.50 is 13.49 percent larger than 1.32.) Agriculture’s share was 4.17 percent in 1990a and 3.62 percent in 2000a, representing a decline in share of expenditures of 13.24 percent. In contrast to NS which can only have positive values, ΔNS can be either positive or negative. In order to equalize ΔNS to NS, the largest value of ΔNS was equated to one. In the national market Political Science had the largest ΔNS at 27.20 percent and this value was used as the denominator for all values of ‘Percent Change in Share of National Spending’. Completing the earlier Agriculture example, the decline of 13.24 percent in share, divided by 27.20 produced a ΔNS for Agriculture of -0.4868. The concept of ΔNS is that portfolio components that grow relatively rapidly are absorbing resources at a faster rate than other portfolio components. In the case of a zero-sum game, such as exists in the national market, resource absorbing portfolio components are taking resources from other components. The decisions that result in these allocations represent strategic activation.

**MSI:** The Market Strategic Indicator (MSI) is the sum of NS and ΔNS.

**Mean MSI:** The arithmetic mean MSI is the Sum of all Fields for MSI (which is 0.1721) divided by 21, which is equal to 0.0082.

**IS:** The Equalized Values for Percent of Institutional Spending (IS) indicates the equalized values for the proportion that each field represented of an RIU’s federally financed research expenditures in 2000a. The first step in generating IS for a field is to determine the percentage that each field represented of the institution’s research expenditures in 2000a. For example, Chemistry was 3.65 percent of the \$298.563 million spent by the University of Pennsylvania in 2000a. This data can be seen in the column entitled ‘2000a Percent of Institutional Spending’ on Figure D. Since IS comprises one of two equal parts of ISI, an indicator defined below, all values

of ‘2000a Percent of Institutional Spending’ were adjusted by the factor that equated the largest value to one. At the University of Pennsylvania, Medical had the largest share in 2000a at 51.02 percent and this value was used as the denominator for all values of ‘2000a Percent of Institutional Spending’. For example, Chemistry was 3.65 percent of the University of Pennsylvania’s expenditures in 2000a. When divided by 51.02, the value of IS for Chemistry equals 0.0716. As is the case for NS, IS relies on the concept that the greater the proportion that a portfolio component represents of an organization’s total portfolio, the greater is its strategic importance.

**ΔIS:** The Equalized Values for Change in Share of Spending (ΔIS) represents the equalized values for the change that occurred in the proportion that each field represented of an RIU’s federally financed research expenditures between 1990a and 2000a. ΔIS is determined by finding the percentage change of ‘2000a Percent of Institutional Spending’ as compared with ‘1990a Percent of Institutional Spending’. For example, at the University of Pennsylvania, Sociology was 0.79 percent of spending in 1990a and 0.97 percent in 2000a which means that its share of institutional expenditures grew by 23.04 percent during the period. (0.97 is 23.04 percent larger than 0.79.) Physics’ share was 5.39 percent in 1990a and 3.77 percent in 2000a, representing a decline in share of expenditures of 30.03 percent. In order to equalize ΔIS to IS, the largest value of ΔIS was equated to one. At the University of Pennsylvania, Political Science had the largest ΔIS at 77.89 percent and this value was used as the denominator for all values of ‘Percent Change in Share of Institutional Spending’. Completing the earlier Physics example, the decline of 30.03 percent in share, divided by 77.89 produced a ΔIS for Physics of -0.3855. As is the case with ΔNS, the concept of ΔIS is that, in a limited resource environment, portfolio components that grow relatively rapidly are absorbing resources faster than other portfolio components. The decisions that enable these resource allocations represent strategic activation.

**ISI:** The Institutional Strategic Indicator (ISI) is the sum of IS and ΔIS.

**Mean ISI:** The arithmetic mean ISI is equal to the sum of the ISI’s from all RIU’s (which is 113.4242) divided by the total number of fields reported by all RIU’s (which is 628). The mean ISI is 0.1806.

**ΔMS:** The Change in Share of the National Market (ΔMS) is the percentage difference in the share of the national market held by an RIU in 2000a as compared

with 1990a. The national market share held by an RIU in 1990a is determined by dividing its Total Reported for 1990a by the Sum of all Fields in the national market in 1990a. Dividing the University of Pennsylvania's Total Reported in 1990a of \$128.994 million by the national market's Sum of all Fields in 1990a of \$8,634.825 million produces a market share of 1.49 percent. Determining the University of Pennsylvania's 2000a share of the national market entails dividing its Total Reported in 2000a of \$298.563 million by the national market Sum of all Fields in 2000a of \$16,056.698 million producing a market share of 1.86 percent. This makes it possible to state that the University of Pennsylvania's share of the national market grew by 24.47 percent during the period. (1.86 is 24.47 percent larger than 1.49.)  $\Delta$ MS is the critical measurement of strategic success in this study since it measures the actual performance of an RIU in relation to all other RIU's and in relation to the national market. Any RIU that has increased its market share to a greater degree than its competitors has achieved a better strategic outcome.

In the final stage of this methodology, each RIU's research portfolio was plotted on a graph called the Strategic Portfolio Array in which the x-axis is ISI and the y-axis is MSI. Quadrants are formed by an x-axis intercept at the Mean ISI and a y-axis intercept at the Mean MSI. The chart, which in some respects echoes the Boston Consulting Group Growth-Share Matrix (Henderson, B., 1973), displays the number of points or incidents that occurs in the quadrants which are then counted for each RIU. Each array represents the realized strategy (Mintzberg, H., and Waters, J. A., 1985) of an RIU in that it can be observed which fields were more or less important during the study period. A correlation was then made between the variance among the number of incidents in the quadrants and the  $\Delta$ MS's of the RIU's.

### Selecting and Accessing Data

Federally funded research is that source of research funding that has been the sustaining source of funds upon which America's public research capacity and capability has been built and within which America's RIU's compete (Rosensweig, R., 1992). The NSF presents federally funded research data in two forms. The first is a survey series generally entitled, "Federal obligations for research to universities and colleges." (NSF c., NSF d.) This form was not used because some research funding obligations span several periods and, in some instances the obligations may not have been satisfied. Both of these factors tend to add unnecessary complications. The selected form was a survey series generally entitled, "Federally financed R&D

expenditures at universities and colleges." (NSF c.) The NSF provides this survey data for all recipients of federal research funds, broken down by science and engineering field, for annual periods beginning in 1972. These data were used because they reflect a current cash accounting methodology wherein each survey participant reports the research it performed in each annual period, regardless of when the funding was received. Thus, a clean 'cut-off' is achieved. Importantly, from 1988 through 2002, the NSF's survey methodology, including field definitions, data reporting instructions, corrections for errors and omissions, and data presentation, did not change in any way that would materially impact the results of this study. However, users of NSF data should access the most currently available surveys because minor adjustments are made when reporting institutions provide updated information in subsequent reporting periods.

The two main categories of data that were collected for this study were for the national market and for each RIU:

### National Market Data

For the national market, the required data were retrieved from various NSF websites (NSF c.; NSF d.). A chart was set up on a Microsoft Excel spreadsheet to receive the data from the NSF websites on which the y-axis was the NSF fields and on which the x-axis was the years 1987 through 2002 inclusive (see Figure A). For convenience purposes, the order in which the fields were reproduced on the sheet matched the NSF surveys and remained consistent across the national market chart and those of the RIU's. A row at the bottom of the national market chart, labeled the Sum of all Fields, represents the total of federally financed R&D reported in fields as spent by colleges and universities in each year.

Prior to using the data in the model it was examined for anomalies to ensure that study results were not skewed by the inadvertent inclusion of unusual events. It is important to note that the steps used to prepare the national market data were also applied to the data of each RIU.

The three most obvious irregularities in the national market data were that the reporting of research activity in the field of BioEng begins only in 1999, reporting in the field of Metal & Mat. begins only in 1990, and that the nature of the research activities that occurred in all fields in which the acronym, "nec" appeared (NSF c.) required an accurate description or would have to be disqualified from use in the study.



Extrapolation was used in cases where there were missing years of data and where this technique provided a result that was reasonable in the circumstances. The Extrapolation Rules used to establish whether extrapolation provided results that were reasonable were as follows:

(1) At least three consecutive years of data were required to extrapolate the next consecutive year at either end of the known series, but not both;

(2) At least four consecutive years of data were required to extrapolate the two consecutive years at either end of the known series, but not both;

(3) At least six consecutive years were required to extrapolate the next three consecutive years at either end of the known series, but not both;

(4) The maximum number of known years was always used;

(5) The maximum number of years that could be extrapolated was three;

(6) No datum was used to extrapolate more than once.

The method used to extrapolate missing data was to determine the slope of a line using the first and last values in the known series. When divided by two, the average annual change in expenditures results. This amount was added or subtracted, as appropriate, to the last known series value to provide the extrapolated value of expenditures for the next year. The final step was repeated when multiple years were being extrapolated.

The Extrapolation Rules enabled establishing values of research expenditures for Metal & Mat. in 1989 of \$130,453 thousand and in 1988 of \$121,744 thousand. The method described required the disqualification of BioEng as a usable field in this study.

The exclusion of all “nec” fields was an important decision because, in some disciplines, it represented a significant proportion of the total. For example, “nec” represented between 21.2 and 35.5 percent of expenditures in the Engineering Sciences in the years 1987 to 2001. At the risk of sounding glib, the problem arose when trying to define what research was being done. The NSF’s definition was such that it was possible for an RIU to classify the

same research differently from year to year or for the same research to be classified differently across RIU’s. In addition, “nec” research may have been comprised of one-time events, projects that were incomplete, or that, as was the case in Metal and Mat. and BioEng, grew to a size sufficient for the NSF to establish a separate field. All of these examples are meant to support the notion that the research that occurred in “nec” fields was unknowable and transient, which could not be understood as a strategic thrust. As such, all “nec” fields were disqualified from the study.

After making the aforementioned adjustments, which included the disqualification of all “nec” fields and BioEng, the 21 remaining fields and the Sum of all Fields comprised the national market data used in this study (see Figure A). The same 21 fields were used for the RIU’s.

The next step was to check for anomalies in the data presented in each field. This was important to negate the possibility that the expenditures in any field in the component years of 1990a or 2000a were exceptional. The threshold used to capture these exceptions had to balance the dampening effect inherent in the defined terms of 1990a and 2000a against the reality that research expenditures in some disciplines fluctuated widely from year to year. As a consequence, it was determined that only very low probability events should trigger an additional adjustment. The Exceptions Methodology used was as follows:

(i) The procedure was undertaken for each field

(ii) The percentage change from one year to the next year was determined for all years beginning with the percentage difference from 1988 to 1989 and ending with the percentage difference from 2000 to 2001.

(iii) The arithmetic mean of the percentage changes was determined. There were 13 percentage changes.

(iv) An amount equal to two standard deviations of the percentage changes was determined.

(v) A range equal to the mean determined in point (iii), plus or minus two standard deviations, as determined in point (iv) was established.

(vi) Each percentage change was compared with the range and all amounts that out lay the range were identified.

(vii) If any of the identified amounts were from the years 1989, 1990, or 1991, then an adjustment was triggered.

(viii) The adjustment affected 1990a only in the specific field in which the exception occurred. The adjustment was that, instead of using the arithmetic mean of data from the years 1989, 1990, and 1991 to establish 1990a, the arithmetic mean of the five years of 1988 to 1992 inclusive was used.

(ix) Likewise, if any of the identified outliers were from 1999, 2000, or 2001, then an adjustment was triggered such that 2000a became the arithmetic mean of data from the five years 1998 to 2002 inclusive.

In the national market, Aero/Astro, Electrical, Astronomy, and Medical for 2000a were adjusted as described.

## Processing the Data

The national market data were now adequately prepared for use in the model as shown on Figure B.

(a) The first column to the right of the field names is 1990a. The Sum of all Fields displays the total of the 21 field values, which was \$8,634,825 thousand. It is important to note that the Sum of all Fields for 1990a is not necessarily equal to the arithmetic mean of data from 1989, 1990, and 1991, since some field values may be the arithmetic mean of five years. Coincidentally, the Sum of all Fields for 1990a is the arithmetic mean of the Sum of all Fields in 1989, 1990, and 1991, but this is not true for the Sum of all Fields for 2000a.

(b) The next column, entitled 1990a Percent of National Spending, is the percent that each field represented of total spending in 1990a. For example, expenditures in Electrical in 1990a of \$418,109 thousand were 4.84 percent of the 1990a Sum of all Fields which was \$8,634,825 thousand. This calculation was made for each field and, by definition, the Sum of all Fields for this column is 100.00 percent.

(c) The following two columns respectively are 2000a and 2000a Percent of National Spending and were created using the same procedure described in point (a) and (b) above. As a matter of confirmation, the Sum of all Fields for 2000a was \$16,056,698 thousand and was 100.00 percent for 2000a Percent of National Spending.

(d) Percentage change in Share of Spending is the name of the next column, a name that accurately reflects its meaning. This column represents the percentage change from 1990a Percent of National Spending to 2000a Percent of National Spending. For example, Ocean was 3.03 percent of national spending in 1990a and was 2.65 percent of national spending in 2000a, a decline of 12.68 percent (2.65 is 12.68 percent less than 3.03). In the column entitled Percent Change in Share of Spending, this result appears as -12.69. There is no need to determine the Sum of all Fields for this column although, as a separate statistic, and at the risk of confusing the meaning of this column, it is interesting to note that the nominal value of the national market grew by 85.95 percent during the study period.

(e) The following two columns are NS and  $\Delta$ NS respectively (see Definitions). There is no need to determine the Sum of all Fields for these columns.

(f) The final column is MSI. MSI for each field is the sum of NS and  $\Delta$ NS and is a factor representing the strategic market opportunities that each field holds for the RIU's. The greater the value of MSI, the more market potential there is.

## RIUs

Institutional Strategic Indicators (ISI's) were determined for the RIU's using, with notable exceptions and additions, the same operations that were used to determine the national market MSI's. Using the example of the University of Pennsylvania, the following steps were followed to determine the ISI's for every RIU.

A chart was set up on a Microsoft Excel spreadsheet to receive data accessed from the NSF's Caspar website (NSF d.) and using the procedure described on Appendix B. The chart's x-axis is the years 1988 to 2002 inclusive and the y-axis is the 21 fields. At the bottom of the y-axis are two rows labeled Total Reported (which is equal to the sum of the fields on the chart), and Total Actual (which is equal to Total Reported plus all disqualified fields). Total Actual data were required only for the years 1989, 1990, 1991, 1999, 2000, and 2001. All fields were subjected to the Extrapolation Rules and the Exceptions Rule, the results of which are displayed on Figure C. Notably, the University of Pennsylvania reported research activity in 16 fields.

Once the above described operations were complete, the data were ready to use in the model as displayed on Figure D:

(a) The first column to the right of the field names is the defined term 1990a. At the bottom of this column is the Total Reported and the Total Actual for 1990a.

(b) The next column, entitled 1990a Percent of Institutional Spending, is the percent that each field represented of the Total Reported in 1990a. For example, at the University of Pennsylvania, expenditures in Psychology of \$1,465 thousand in 1990a were 1.14 percent of the 1990a Total Reported of \$128,994 thousand.

(c) The next column is called 1990a Percent of National Spending. The important figure in this column is the Total Reported which is the national market share held by the RIU in 1990a. Specifically, this figure is determined by dividing the Total Reported in 1990a of \$128,994 thousand by the national market Sum of all Fields for 1990a of \$8,643,825 thousand which is equal to 1.49 percent.

(d) The next column is the defined term 2000a. At the bottom of this column is the Total Reported and Total Actual for 2000a which, once known, can be used in conjunction with the 1990a data to run the Reporting Variance test. Since the University of Pennsylvania's reported variance was -1.38 percent, it qualifies as an RIU.

(e) The next two columns are 2000a Percent of Institutional Spending and 2000a Percent of National Spending which are derived using the same method as was used in steps (b) and (c) above with the exception that 2000a data were used instead of 1990a data. Importantly, the Total Reported for 2000a Percent of National Spending was 1.86 percent.

(f) The next column, entitled Percent Change in Share of National Spending, is determined by finding the percentage difference between 1990a Percent of National Spending and 2000a Percent of National Spending. The important figure in this column is the Total Reported since this is  $\Delta$ MS for this institution (see Definitions). Specifically, the Total Reported for the Percent Change in Share of National Spending was 1.49 in 1990a and was 1.86 in 2000a resulting in an increase in market share over the study period of 24.47 percent (that is, 1.86 is 24.47 percent larger than 1.49).  $\Delta$ MS for the University of Pennsylvania is 24.47. From a practical perspective, it is important for an RIU to understand how it is performing in each field in its research portfolio. While not specifically used in this study, the national share for 1990a, 2000a, and the Percent

Change in Share of National Spending has been determined for each field for every RIU.

(g) The next column is the Percent Change in Share of Institutional Spending. Using the earlier example of Psychology, at the University of Pennsylvania 1990a Percent of Institutional Spending was 0.87 percent and was 0.85 percent in 2000a which means that Psychology's share of spending declined by 2.64 percent during the study period (that is, 0.85 is 2.64 percent less than 0.87). The Percent Change in Share of Institutional Spending is determined for all fields.

(h) The following two columns are IS and  $\Delta$ IS respectively (see Definitions). There is no need to determine the Sum of all Fields for these columns.

(i) The final column is ISI. ISI for each field is the sum of IS and  $\Delta$ IS and is a factor representing the strategic priority that each field is to an RIU. The greater the value of ISI, the more strategically important it is to the RIU.

(j) A Strategic Portfolio Array is created for each RIU as displayed on Figure E. The four quadrants are formed by an x-axis intercept at the Mean ISI (which is 0.1806, see Definitions) and a y-axis intercept at the Mean MSI (which is 0.0082, see Definitions). The quadrants are hereafter referred to as the northwest (NW), northeast (NE), southwest (SW), and southeast (SE).

(k) Each field is plotted on the array such that the value of "x" is ISI and the value of "y" is MSI for coordinate points at (ISI, MSI). For example, ISI for Chemical at the University of Pennsylvania was -0.2972 and MSI for Chemical was -0.106 creating a coordinate point or incident for Chemical at (-0.2972, -0.106). This incident occurs in the SW quadrant. All fields where research activity was reported are plotted on a separate array for each RIU.

(l) The number of incidents in each quadrant were counted and recorded.

## Calculating the Results

$\Delta$ MS, the number of fields in which research activity was reported, and the number of incidents that occur in each quadrant is now known for each RIU. Figure F displays the compilation of this data.

(i) The first two columns of Figure F are the RIU's sorted in descending order according to their  $\Delta$ MS's. For

example, the University of Pennsylvania, which is fifth from the top, had a  $\Delta MS$  of 24.47.

(ii) The next column is the number of fields in which research activity was reported for each RIU. For example, the University of Pennsylvania reported activity in 16 fields. At the base of this column is the total of the number fields reported by all RIU's followed by the mean number of fields per RIU which was 16.10. In other words, during the study period, the average RIU reported federally financed research in slightly more than 16 fields.

(iii) The next four columns record the number of incidents that occurred in the quadrants of each RIU's Strategic Portfolio Array. Following the example of the University of Pennsylvania, there were no incidents in the NW quadrant, four in the NE, 10 in the SW, and two in the SE quadrant. At the base of each of these four columns is their correlation to  $\Delta MS$ , the total number of incidents that occurred in the quadrant, and the mean number of incidents. For the entire population of RIU's, the average number of incidents in the NW quadrant was 2.62, there were 3.31 in the NE, 7.31 in the SW, and 2.87 in the SE quadrant. On average, the SW quadrant had more than twice the number of incidents of any other quadrant. The SW quadrant is 45.4 percent of the average number of fields (7.31 divided by 16.10). The correlation to  $\Delta MS$  is critical in this study as it provides insight into the relationship between the number of incidents that occurred in various quadrants of the RIU's and their market performance as expressed by  $\Delta MS$ . While interpretations of this data are presented elsewhere (see Interpretation), it can be said that at -0.32 there does appear to be a moderate inverse relationship between the SE quadrant and  $\Delta MS$ . That is, as  $\Delta MS$  declines, the average number of incidents in the SE quadrant will tend to increase. At 0.29, a slightly weaker but direct relationship exists between the SW quadrant and  $\Delta MS$ .

(iv) The following series of columns are analytic attempts to find the combination of quadrants that yields the highest correlation. Each combination employs the principal that every institution's mix of portfolio components is relative only to the portfolio of which it is a part. In other words, every set of IS and  $\Delta IS$ 's are specific to the portfolio of the RIU from which they were derived. Methodologically, this requires that the number of incidents in the quadrants of any RIU be viewed in relation to the number of fields in which that RIU reported research activity. In this way, a ratio is produced whereby the number of incidents in a quadrant or combination of quadrants is always divided by

the number of fields in which research was reported by the corresponding RIU. Following the example of the University of Pennsylvania, the column entitled "SW/#fields" was determined by dividing the number of incidents in the SW quadrant (10) by the number of fields (16) to produce the ratio 0.63. Significantly, this method yields a correlation between the "SW/#fields" column and  $\Delta MS$  of 0.41 which is a stronger result than the 0.29 produced without using the ratio method. In Figure F all analytic columns use the ratio method.

(v) The analytic columns on Figure F represent attempts to find those quadrants or combination of quadrants that produce the strongest correlation. As earlier mentioned, each combination uses the ratio method. For example, the second analytic column is labeled Max Spread/#fields. This is the largest number of incidents in any quadrant of an RIU less the smallest number of incidents in any quadrant. The 0.41 correlation indicates that the greater the spread, the more likely that there will be better market performance. In addition, combinations were tested to determine whether any strategic trend was emerging from the data and many of the test columns are not shown. Notably, there can never be a perfect correlation since there can never be a perfect strategy that was perfectly planned and perfectly executed. In the case of universities, Baldrige, Curtis, Ecker, and Riley's (1986) argument that varied and often conflicting goals serves to emphasize this point.

## Interpretation

In order to more completely present the results of this study, the Strategic Portfolio Array and its component parts should be more thoroughly understood. A preliminary description follows:

The NE quadrant may be the most straightforward to describe in that it is populated with an RIU's largest and fastest growing fields which are in the largest and fastest growing market segments. While an RIU should want as many fields as possible in the NE quadrant, moving fields into this quadrant will usually require a substantial investment. Fields in this quadrant are strategically important to an RIU in that any significant shock could have repercussions for the RIU beyond the directly corresponding loss of research revenue. This raises the issue of intensity in that a shock to a field represented by an incident that is a greater distance from the source than others is likely to have a greater impact on the RIU. In addition, the juxtaposition of an incident to a line which is 45 degrees from the x-axis can provide other types of insights. For example, an



incident that occurs above the 45 degree line may represent increased susceptibility to market fluctuations. Below the line occurrences may represent, depending on the actual size of the market segment, unsustainably large market shares. In all cases, retention of human capital is essential to maintaining operations in the NE quadrant. An additional factor to consider in respect of the NE quadrant is that fields with low dollar values of research can have exaggerated  $\Delta$ IS's because small changes tend to have a large effect on the Percent Change in Share of Institutional Spending. This suggests a limitation for the practical use of the model in its current form. However, for the purposes of this phase of the study, the methodology will not go beyond the already described processes.

The NW quadrant is interesting for several reasons including the notion that time could be a more significant analytic factor than other fields. This quadrant represents a situation in which fields are low priority to RIU's but operate in important market segments. The time factor is important to know because RIU's that have incidents in this quadrant may be at the early stages of attempting to develop high priority fields that would eventually reside in the NE quadrant. Alternative situations, in which an incident has been in the NW quadrant for an extended period, could mean either a missed opportunity or that an RIU is satisfied to be a very minor niche player in an important market segment. Perhaps an RIU simply wants to maintain a presence in the market. A vector analysis, whereby the direction of movement of an incident over time as well as its inertia, would provide the kind of dynamic view of an RIU's array that would help answer some of these questions. Incidents in this quadrant should be considered unstable and are likely to drift towards the NE quadrant given the influence that powerful market forces can exert. Incidents in this quadrant represent the best opportunities for growth.

The SE quadrant represents fields that are very important to an RIU but operate in low potential markets. On the surface this seems like a high risk situation in that an RIU may be overly reliant on a field in which it holds an unsustainably large market share. However, there may be instances where the market size is substantial enough to support some relatively large players. In this regard, the risk factor could be determined by a market concentration measurement such as a Herfindahl analysis. Another important aspect of the SE quadrant is that it would be most difficult to move a field into the NE quadrant. In cases that could be considered as high risk, a vector analysis could

help an RIU understand whether its exposure to limited markets is increasing or diminishing. This points to the inherent instability in this quadrant where fields are likely to drift towards the SW. RIU's with fields in this quadrant are destined to be niche players.

Finally, the SW quadrant is populated by fields that are of strategically low value to RIU's and that operate in markets that are relatively small and may also be contracting. The somewhat negative connotation suggested by this description is not necessarily reflective of what is the more probable reality. The story of the SW quadrant may lie in the notion that all RIU's are, to varying degrees, comprehensive institutes of higher education. Fields such as Mathematics, Economics, or humanities and other disciplines that are outside of the realm of this study enhance comprehensiveness and as a consequence, can lead to an interpretation of the SW quadrant that could be called the sustaining fields. That is, the vitality of a comprehensive university may be evidenced by the academic activity occurring in the fields in this quadrant. In this regard, the SW quadrant represents fields that help RIU's sustain their comprehensive make-up.

## Conclusion

The methodology presented in this paper is a step forward in the development of quantitative tools that can be used to more directly observe the research strategies realized by RIU's as well as whether those strategies have had a positive or negative result. As a consequence, new management and accountability tools may become available for those involved in the operation and control of research operations in higher education.

The study itself suggests that those RIU's that realized a specialization strategy increased their market share to a greater degree than RIU's that realized other strategies or than those whose strategies were a less pure manifestation of specialization. A specialization strategy is reflected by an organization's repeated allocation of disproportionately large amounts of its resources to the same portfolio component so that, after a certain period of time, that component's strategic value to the organization becomes accentuated. Notably, specialization and differentiation strategies are different. In multi-unit enterprises, differentiation relates to second stage resource allocation decisions about the goods and services offered by an enterprise in relation to competitors. Specialization is a consequence of primary resource allocation decisions which, as Mintzberg (1972), Porter (1996), and Ansoff (1988) would suggest, is the

basic manifestation of strategy. For example, primary strategic decisions relate to where in the organization resources should be allocated while secondary decisions are more related to how to spend them. The two strategies are not mutually exclusive. Indeed, in order for an RIU to enjoy market success it must employ both. In practical terms, RIU's must invest, at an accelerated rate, in fields in which the underlying research is differentiated from other RIU's research in those fields. In that way, research funding is won and, to use a colloquialism, success breeds success.

A pure specialization strategy would present on a Strategic Portfolio Array as a single incident in the NE quadrant with all remaining incidents in the SW quadrant. Such a position would be a recognition that incidents that occur in the NW and SE quadrants are, from a market perspective, inefficient and as a consequence, diminish an RIU's ability to advance against competitors. The results of this study support this notion as evidenced by the -0.46 correlation between the analytic column labeled NW+SE with  $\Delta$ MS. This relatively strong correlation is interpreted to mean that the fewer the relative number of incidents in the NW and SE quadrants, the better will be an RIU's relative market performance. The 0.46 correlation between SW+NE and  $\Delta$ MS describes the complementary relationship to the above whereby the greater the proportion of incidents that occur in the SW and NE quadrants, the better an RIU's market performance is likely to be.

A significant discrepancy exists between the view of a pure specialization strategy, where there would be a single incident in the NE quadrant, and the expected desire of every RIU to have as many incidents as possible in the NE quadrant. The research shows that the average RIU has between three and four incidents in the NE quadrant and that the correlation of NE to  $\Delta$ MS, at 0.13, is weak. As such, providing an RIU has a number of incidents in the NE quadrant that is at least 3 (the mean number of incidents in the NE quadrant, less the standard deviation, is more than two), it has the potential to be a market out-performer. However, the number of incidents in the NE quadrant is not an indicator of market performance. Having made this point, it should be added that the degree of intensity may reveal additional insights which, as earlier described, relates to the distance of incidents from the source.

The differentiating factor in this research is in the relative number of incidents in the SE quadrant and, more importantly, in the NW and SE quadrants, as the previously highlighted correlation shows. The conclusion to be drawn

from this research is that RIU's with at least three fields of specialization and more of their remaining fields in the SW quadrant than otherwise, are most likely to be market out-performers.

## REFERENCES

- Ansoff, H. Igor., assisted by McDonnell, Edward, J. (1988). *New Corporate Strategy*. John Wiley & Sons, Inc. New York.
- Association of American Universities. Retrieved March 28, 2005 from <<http://www.aau.edu/members.html>>
- Baldrige, J. Victor, Curtis, David V., Ecker, George P., and Riley, Gary L. (1986). *Alternative Models of Governance in Higher Education*. In *ASHE Reader in Organization and Governance in Higher Education*. Lexington, Mass.: Ginn Press.
- Barney, Jay B. (2001). Is the Resource-based "view" a useful perspective for strategic management research? Yes. *Academy of Management. The Academy of Management Review*. Vol. 26 (1).
- Ben-David, J. (1972). *Trends in American Higher Education*. Chicago: The University of Chicago Press.
- Birnbaum, R. (1983). *Maintaining Diversity in Higher Education*. San Francisco: Josey – Bass.
- Boyd, Brian K. (1991). Strategic Planning and Financial Performance: A Meta-analytic Review. *Journal of Management Studies*. Vol. 28 (4).
- Braxton, John M., and Boyer, Allen E. (1986). Chapter II. In Cresswell, John W., (Ed.). *Measuring Faculty Research Performance. New Directions for Institutional Research*. Vol. 50. Josey-Bass Inc.: San Francisco.
- Carnegie Foundation for the Advancement of Teaching a. Retrieved March 28, 2005 from <<http://www.carnegiefoundation.org/Classification/CIHE2000/PartIfiles/DRU-EXT.htm>>
- Carnegie Foundation for the Advancement of Teaching b. Received by Facsimile on March 30, 2005 from Carnegie Foundation for the Advancement of Teaching, Jacki Calvert.
- Clark, Burton. (1992). Chapter 11. In Whiston, Thomas G., and Geiger, Roger L., (Eds.). *Research and Higher Education: The United Kingdom and the United States*. SRHE and Open University Press, Buckingham, United Kingdom and Bristol, Pennsylvania.
- Dill, David D. (1997). Higher Education Markets and Public Policy. *Higher Education Policy*. Volume 10 (3/4).

- Etzkowitz, Henry, Webster, Andrew, and Healey, Peter. (1998). *Capitalizing Knowledge: New Intersections of Industry and Academia*. SUNY Series, Frontiers of Education. Albany State University of New York Press.
- Feller, Irwin. (2000). Strategic Options to Enhance the Research Competitiveness of EPSCoR Universities. In Hauger, J. Scott, and McEnaney, Ceilia, (Eds.). *Strategies for Competitiveness in Academic Research*. American Association for the Advancement of Science. Retrieved January 12, 2006 from <<http://www.aaas.org/spp/rcp/strategy/htm>>
- Feller, Irwin, and David Roessner. (1995). What Does Industry Expect From University Partnerships? *Issues in Science and Technology*. Vol. 12 (1).1995.
- Geiger, Roger L. (2004). *Knowledge and Money: Research Universities and the Paradox of the Marketplace*. Stanford University Press. Stanford, California.
- Geiger, Roger L, and Feller, Irwin. (1995). The Dispersion of Academic Research in the 1980's. *Journal of Higher Education*. Vol. 66 (3).
- Glasgow University a. RAE 2001 UoA Analysis. Retrieved June 16, 2005 from <<http://www.gla.ac.uk/R-E/pub/rae/uoa-comparison2001.xls>>
- Glasgow University b. RAE 2001 Research Weight. Retrieved June 16, 2005 from <<http://www.gla.ac.uk/R-E/pub/rae/ukweight2001.xls>>
- Hauger, J. Scott. (2000). Chapter Two: Strategic Planning for Research Competitiveness. In Hauger, J. Scott, and McEnaney, Ceilia, (Eds.). *Strategies for Competitiveness in Academic Research*. American Association for the Advancement of Science. Retrieved January 12, 2006 from <<http://www.aaas.org/spp/rcp/strategy/htm>>
- Henderson, Bruce D. (1972). The Experience Curve – Reviewed. IV. The Growth Share Matrix or the Product Portfolio. The Boston Consulting Group Reprint Number 135. Retrieved November 7, 2005 from <<http://www.bcg.com/publications/files/experiencecurveIV.pdf>>
- Jankowski, John E. (1999). Trends in Academic Research Spending, Alliances, and Commercialization. *Journal of Technology Transfer*. Vol. 24, (April).
- Keller, George. (1983). *Academic Strategy: The Management Revolution in American Higher Education*. The Johns Hopkins University Press, Baltimore.
- Lang, Daniel W. (August, 2004). What is a World Class University? Paper presented to Beijing Forum. Beijing, China.
- Lang, Daniel W. (2000). Similarities and differences: Measuring diversity and selecting peers in higher education. *Higher Education*. Vol. 39.
- Liu, N.C., and Cheng, Y. (2005). Academic Ranking of World Universities – Methodologies and Problems. *Higher Education in Europe*. Vol. 30 (2).
- Markowitz, Harry. Foundations of Portfolio Theory. Nobel Lecture, December 7, 1990. Retrieved January 16, 2006 from <<http://nobelprize.org/economics/laureates/1990/markowitz-lecture.pdf>>
- Massy, William F., and Robert Zemsky. (1994). Faculty Discretionary Time: Departments and the “Academic Ratchet”. *The Journal of Higher Education*. Vol. 65 (1).
- Mintzberg, Henry, and Waters, James A. (1985). Of Strategies, Deliberate and Emergent. *Strategic Management Journal*. Vol. 6 (3).
- Mintzberg, Henry. (1972). Research on Strategy-Making. Proceedings of the 32nd Annual Meeting of the Academy of Management, Minneapolis.
- Naylor, Thomas H., and Tapon, Francis. (1982). The Capital Asset Pricing Model: An Evaluation of its Potential as a Strategic Planning Tool. *Management Science*. Vol. 28 (10).
- NSF a. Retrieved September 20, 2005 from <<http://www.nsf.gov/statistics/nsf0433-/pdf/sectb.pdf>>
- NSF b. Retrieved September 26, 2005 from <[http://www.nsf.gov/statistics/rdexp97/dug97/s\\_efield.htm](http://www.nsf.gov/statistics/rdexp97/dug97/s_efield.htm)>
- NSF c. Retrieved on various dates in 2005 from <<http://www.nsf.gov/statistics/rdexpenditures/dst/92dst.htm>> and <<http://www.nsf.gov/statistics/rdexpenditures/95dst/b/pdf/b4.pdf>> and <<http://www.nsf.gov/statistics/nsf04330/pdf/sectb.pdf>>
- NSF d. Retrieved on various dates in 2005 from <<http://caspar.nsf.gov>>
- NSF e. Retrieved January 19, 2005 from <<http://www.nsf.gov/statistics/nsf05320/pdf/tables.pdf>>
- NSF f. National Science Foundation, Support for academic R&D, by sector: 1953-2000. Retrieved March 8, 2005 from <<http://www.nsf.gov/sbe/srs/seind02/append/c5/at05-02.xls>>

- NSF g. Retrieved December 15, 2005 from <<http://www.nsf.gov/statistics/nsf02308/pdf/sectb.pdf>> and <<http://www.caspar.nsf.gov>>
- O'Leary, John. (November 5, 2004). Top performers on the global stage take a bow. World University Rankings Editorial. *The Times Higher Education Supplement*.
- Pennsylvania State University. Office of the Vice President for Research: Strategic Plan 2002 – 2005. Retrieved November 20, 2004 from <<http://www.research.psu.edu/pu/strategicplan.shtml>>
- Porter, Michael E. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press, New York.
- Porter, Michael E. (1996). What is Strategy? *Harvard Business Review*. Vol. 74 (6).
- Research Assessment Exercise. A Guide to the 2001 Research Assessment Exercise. Retrieved June 16, 2005 from <<http://www.hero.ac.uk/rae/Pubs/other/raeguide.pdf>>
- Rosensweig, Robert M. (1992). Chapter 12. In Whiston, Thomas G., and Geiger, Roger L., (Eds.). *Research and Higher Education: The United Kingdom and the United States*. SRHE and Open University Press. Buckingham, United Kingdom and Bristol Pennsylvania.
- Statistics Canada. (June 2000). *Multinationals and the Canadian Innovation Process*. Report 11F0019MPE No. 151.
- The Center. *The Top American Research Universities*. Retrieved December 7, 2005 from <<http://thecenter.ufl.edu/research2003.html>>



## APPENDIX A

The following constitutes the population of universities that are defined as research intensive in this study. They will be referred to as RIU's.

### Name of Institution

California Institute of Technology  
 Carnegie Mellon University  
 Case Western Reserve University  
 Columbia University  
 Cornell University  
 Duke University  
 Harvard University  
 Indiana University  
 Johns Hopkins University  
 Massachusetts Institute of Technology  
 Michigan State University  
 New York University  
 Northwestern University  
 The Ohio State University (Main Campus)  
 Princeton University  
 Purdue University  
 Rutgers, The State University of New Jersey (New Brunswick Campus)  
 Stanford  
 University of Arizona  
 University of California - Berkeley  
 University of California – Los Angeles  
 University of California – San Diego  
 University of Chicago  
 University of Colorado at Boulder  
 University of Florida  
 University of Iowa  
 University of Maryland (College Park)  
 University of Michigan-Ann Arbor  
 University of Minnesota-Twin Cities  
 University of Missouri-Columbia  
 University of North Carolina at Chapel Hill  
 University of Pennsylvania  
 University of Rochester  
 University of Southern California  
 University of Virginia  
 University of Wisconsin-Madison  
 Vanderbilt University  
 Washington University  
 Yale University

### Sources:

Association of American Universities (AAU)  
 Carnegie Foundation for the Advancement of Teaching a.

### Future Referencing

Cal Tech  
 Carnegie Mellon  
 Case Western  
 Columbia  
 Cornell  
 Duke  
 Harvard  
 Indiana University  
 Johns Hopkins  
 MIT  
 Michigan State  
 New York University  
 Northwestern  
 Ohio State  
 Princeton  
 Purdue  
 Rutgers  
  
 Stanford  
 University of Arizona  
 UC-Berkeley  
 USLA  
 UC-San Diego  
 University of Chicago  
 University of Colorado  
 University of Florida  
 University of Iowa  
 University of Maryland  
 University of Michigan  
 University of Minnesota  
 University of Missouri  
 University of North Carolina  
 University of Pennsylvania  
 University of Rochester  
 USC  
 University of Virginia  
 University of Wisconsin  
 Vanderbilt University  
 Washington University  
 Yale

**APPENDIX B****Procedure for Accessing RIU Research Data**

For the RIU data, the following procedure is followed:

Go to <<http://caspar.nsf.gov>> (NSF d.)

Choose “Data Source” and select “NSF Survey of R&D Expenditures at Universities and Colleges”

Click “Select Data Source(s)”

A new page will open

Click the tab entitled “Modify Analysis Variables”

At the bottom of the page is a box. Choose “Federally Financed Academic R&D Expenditures”

Click “Select”

Click the tab entitled “Modify Classification Variables”

At the bottom of the page is a box. Choose “Academic Institution (standardized)”

Click “Select”

In the bottom box choose “Academic Discipline, Detailed (standardized)”

Click “Select”

Scroll up the page to the section entitled “Year”

For “Display:” choose “Selected Values in Column”

For “Include Total?” choose “No”

For “Selected Values:” click “Edit”

A new page will open.

In the box on the right, any values that appear should be removed, press “Remove all Values”

In the box on the left, choose 1988 through 2002 inclusive.

Click “Add Value(s)” Click “Save”

The page will return to the “Modify Classification Variables” page

Scroll to the section entitled “Academic Institution (standardized)”

For “Display:” choose “Selected Values in Row”

For “Include Total?” choose “Yes”

For “Selected Values:” click “Edit”

A new page will open.

In the box on the right, any values that appear should be removed, press “Remove all Values”

In the box on the left, choose all 39 RIU’s. After selecting each RIU, press “Add Value(s). Do not press “Save” until all RIU’s have been selected.

Once all 39 RIU’s appear in the box entitled “Selected Value(s), press “Save”

The page will return to the “Modify Classification Variables” page

Scroll to the section entitled “Academic Discipline, Detailed (standardized)”

For “Display:” choose “Selected Values in Row”

For “Include Total?” choose “Yes”

For “Selected Values:” click “Edit”

A new page will open.

In the left box, choose only those fields included in the study. Each time a field or group of fields is highlighted, click “Add Value(s)”. Once all fields appear in the box on the right, click “Save”

The page will return to the “Modify Classification Variables” page

At the top of the page click on “View Table”

The table will open. It can then be copy and pasted, exported or transcribed to an Excel file.

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### ***CSSHE Professional File***

The *CSSHE Professional Files* describe and analyse current issues in higher education policy and practice. They offer a critical assessment of the issue under consideration, then suggest alternatives for policy and practice, and identify directions for further research.

Submissions consistent with the purpose of the *CSSHE Professional File* should be submitted to the editor. *CSSHE Professional Files* are published up to four times per year and are distributed free of charge to CSSHE Members (as PDF files by email).

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**FIGURE A**

**NATIONAL MARKET RESEARCH EXPENDITURES BY YEAR BY FIELD (ADJUSTED)**

US\$1,000's (nominal)		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Engineering																
	Aero/Astro	93681	114881	126904	137323	150440	159317	165897	183695	171227	183350	170794	183052	180924	254224	245591
	Chemical	85530	100905	110358	117999	126215	142803	150224	161117	173770	165856	169276	178870	195082	214893	228543
	Civil	102168	102165	116999	123635	143628	154327	162948	185896	197741	200357	197086	216317	236401	270707	307939
	Electrical	330379	386630	431820	435877	449459	458418	489022	543647	599810	624262	692549	649815	699803	725808	817403
	Mechanical	192647	214128	238201	251315	268853	309988	325511	339627	334913	322462	350741	387941	382734	416323	507328
	Metal & Mat	121774	130453	139133	153099	143259	150438	155012	175508	190455	222456	221691	217305	225918	240780	262188
Total Engineering		926179	1049162	1163415	1219248	1281854	1375291	1448614	1589490	1667916	1718743	1802137	1833300	1920862	2122735	2368992
Physical sciences																
	Astronomy	83744	87941	112714	136018	158350	165031	181658	206964	182354	182988	187993	272468	276493	259732	277380
	Chemistry	403189	421957	444902	451087	479583	505138	519951	533165	553613	551700	586982	616442	630049	661223	737272
	Physics	579590	606137	652116	679617	708018	708152	725104	761779	757293	803283	817951	867445	900671	926721	970813
Total Physical Science		1066523	1116035	1209732	1266722	1345951	1378321	1426713	1501908	1493260	1537971	1592926	1756355	1807213	1847676	1985465
Environmental																
	Atmospheric	112318	128806	131110	129384	140073	160634	164582	163653	175954	186622	209549	222376	221834	232150	249567
	Earth/Geol	174483	186777	204497	217945	238155	243221	269221	273899	267005	269073	312143	321182	331598	329146	374089
	Ocean	238249	259916	262090	263521	306461	329467	323586	331516	371406	355498	362204	405278	422144	448065	485727
Total Environmental		525050	575499	597697	610850	684689	733322	757389	769068	814365	811193	883896	948836	975576	1009361	1109383
Mathematics		149959	157289	160868	170485	183194	203039	205694	204772	208042	202052	214133	209229	228647	241653	266788
Computer		289129	323833	342321	371549	379798	423319	463029	483410	501578	506348	513479	582811	582699	643583	769761
Life Sciences																
	Agricultural	322446	349450	352804	377281	417741	449963	496177	531505	559673	548427	533532	545033	578929	617625	685686
	Biological	1608398	1736166	1844230	1950008	2136919	2310115	2448331	2490013	2530066	2684706	2938057	3221331	3653857	3871355	4406305
	Medical	2212866	2502586	2671393	2848670	3113366	3369501	3535380	3826912	4023873	4226915	4559278	4865993	5441833	6260185	7230513
Total Life Science		4143710	4588202	4868427	5175959	5668026	6129579	6479888	6848430	7113612	7460048	8030867	8632357	9674619	10749165	12322504
Psychology		140465	153081	163805	186280	214900	234382	241309	248804	258418	271391	298661	309274	350232	398312	474374
Social Sciences																
	Economics	49171	54316	54346	59669	65945	77301	76011	80029	90659	89803	92250	90114	89072	89938	101378
	Political	25163	25884	25364	28541	35045	42827	50270	59649	62248	51768	53115	54052	62718	71963	75761
	Sociology	47782	53883	59989	72023	81710	91078	96677	104420	118963	120578	118950	121951	136678	148343	180752
Total Social Science		122116	134083	139699	160233	182700	211206	222958	244098	271870	262149	264315	266117	288468	310244	357891
Sum of all Fields		7363131	8097184	8645964	9161326	9941112	10688459	11245594	11889980	12329061	12769895	13600414	14538279	15828316	17322729	19655158

Source: (NSF c.; NSF d.)



**FIGURE B**

**CALCULATION OF MSI**

			1990a		2000a	Percentage	Equalized Values	Equalized Values	
		1990a	Percent of	2000a	Percent of	Change in	for Percent of	for Change in	MSI
			National		National	Share of	National Spending	Share of Spending	
			Spending		Spending	Spending	(NS)	(ΔNS)	
Engineering									
	Aero/Astro	126369	1.46	206917	1.29	-11.95	0.0365	-0.4391	-0.403
	Chemical	109754	1.27	196282	1.22	-3.83	0.0346	-0.1406	-0.106
	Civil	114266	1.32	241142	1.50	13.49	0.0425	0.4958	0.538
	Electrical	418109	4.84	717076	4.47	-7.77	0.1264	-0.2856	-0.159
	Mechanical	234548	2.72	395666	2.46	-9.28	0.0698	-0.3412	-0.271
	Metal & Mat	140895	1.63	228001	1.42	-12.98	0.0402	-0.4770	-0.437
Total Engineering		1143942	13.25	1985083	12.36	-6.68			
Physical sciences									
	Astronomy	112224	1.30	254813	1.59	22.10	0.0449	0.8125	0.857
	Chemistry	439315	5.09	635905	3.96	-22.16	0.1121	-0.8145	-0.702
	Physics	645957	7.48	898279	5.59	-25.22	0.1584	-0.9269	-0.769
Total Physical Science		1197496	13.87	1788997	11.14	-19.66			
Environmental									
	Atmospheric	129767	1.50	225453	1.40	-6.57	0.0398	-0.2415	-0.202
	Earth/Geol	203073	2.35	327309	2.04	-13.32	0.0577	-0.4897	-0.432
	Ocean	261842	3.03	425162	2.65	-12.68	0.0750	-0.4661	-0.391
Total Environmental		594682	6.89	977924	6.09	-11.57			
Mathematics	Mathematics	162881	1.89	226510	1.41	-25.21	0.0399	-0.9269	-0.887
Computer	Computer	345901	4.01	603031	3.76	-6.25	0.1063	-0.2296	-0.123
Life Sciences									
	Agricultural	359845	4.17	580529	3.62	-13.24	0.1024	-0.4868	-0.384
	Biological	1843468	21.35	3582181	22.31	4.50	0.6316	0.1654	0.797
	Medical	2674216	30.97	5671560	35.32	14.05	1.0000	0.5165	1.517
Total Life Science		4877529	56.49	9834270	61.25	8.43			
Psychology	Psychology	167722	1.94	352606	2.20	13.06	0.0622	0.4800	0.542
Social Sciences									
	Economics	56110	0.65	89708	0.56	-14.02	0.0158	-0.5154	-0.500
	Political	26596	0.31	62911	0.39	27.20	0.0111	1.0000	1.011
	Sociology	61965	0.72	135657	0.84	17.73	0.0239	0.6518	0.676
Total Social Science		144672	1.68	288276	1.80	7.16			
Sum of all Fields		8634825	100.00	16056698	100.00				

**FIGURE C**

UNIVERSITY OF PENNSYLVANIA RESEARCH EXPENDITURES BY YEAR BY FIELD (ADJUSTED)

US\$1,000's (nominal)		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Engineering																
	Aero/Astro															
	Chemical	\$ 1,966	\$ 3,452	\$ 1,333	\$ 953	\$ 948	\$ 737	\$ 693	\$ 733	\$ 646	\$ 720	\$ 1,026	\$ 1,282	\$ 1,300	\$ 1,016	\$ 1,697
	Civil	\$ 865	\$ 123	\$ 122	\$ 291	\$ 229	\$ 138	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ -	\$ 46
	Electrical	\$ 1,043	\$ 1,194	\$ 1,189	\$ 1,040	\$ 1,079	\$ 980	\$ 1,136	\$ 1,469	\$ 1,161	\$ 1,163	\$ 896	\$ 844	\$ 235	\$ 517	\$ 1,101
	Mechanical	\$ 596	\$ 342	\$ 710	\$ 916	\$ 1,016	\$ 808	\$ 727	\$ 767	\$ 1,161	\$ 958	\$ 1,495	\$ 1,489	\$ 1,246	\$ 1,323	\$ 1,640
	Metal & Mat	\$ 2,576	\$ 2,567	\$ 2,558	\$ 2,735	\$ 4,499	\$ 4,234	\$ 2,146	\$ 2,366	\$ 2,685	\$ 1,796	\$ 2,860	\$ 2,766	\$ 2,464	\$ 2,405	\$ 3,257
Total Engineering		\$ 7,046	\$ 7,678	\$ 5,912	\$ 5,935	\$ 7,771	\$ 6,897	\$ 4,702	\$ 5,335	\$ 5,653	\$ 4,637	\$ 6,277	\$ 6,381	\$ 5,245	\$ 5,261	\$ 7,741
Physical Sciences																
	Astronomy															
	Chemistry	\$ 6,337	\$ 7,046	\$ 7,330	\$ 8,168	\$ 8,059	\$ 8,642	\$ 9,342	\$ 8,184	\$ 12,181	\$ 10,423	\$ 11,283	\$ 10,624	\$ 11,992	\$ 10,112	\$ 10,158
	Physics	\$ 6,643	\$ 6,553	\$ 7,084	\$ 7,215	\$ 7,417	\$ 6,921	\$ 9,846	\$ 10,666	\$ 10,216	\$ 11,771	\$ 12,043	\$ 12,031	\$ 10,171	\$ 11,569	\$ 11,340
Total Physical Sciences		\$ 12,980	\$ 13,599	\$ 14,414	\$ 15,383	\$ 15,476	\$ 15,563	\$ 19,188	\$ 18,850	\$ 22,397	\$ 22,194	\$ 23,326	\$ 22,655	\$ 22,163	\$ 21,681	\$ 21,498
Environmental																
	Atmospheric															
	Earth/Geol	\$ 12	\$ 19	\$ 41	\$ 129	\$ 158	\$ 93	\$ 188	\$ 94	\$ 98	\$ 26	\$ 20	\$ 29	\$ 92	\$ 164	\$ 38
	Ocean															
Total Environmental		\$ 12	\$ 19	\$ 41	\$ 129	\$ 158	\$ 93	\$ 188	\$ 94	\$ 98	\$ 26	\$ 20	\$ 29	\$ 92	\$ 164	\$ 38
Mathematics	Mathematics	\$ 699	\$ 741	\$ 892	\$ 811	\$ 1,107	\$ 1,166	\$ 1,289	\$ 1,230	\$ 1,422	\$ 1,117	\$ 731	\$ 949	\$ 1,035	\$ 1,014	\$ 1,865
Computer	Computer	\$ 4,193	\$ 5,163	\$ 6,114	\$ 6,139	\$ 5,572	\$ 5,351	\$ 5,282	\$ 5,551	\$ 6,155	\$ 5,789	\$ 5,905	\$ 7,037	\$ 7,664	\$ 7,658	\$ 9,393
Life Sciences																
	Agriculture															
	Biological	\$ 23,419	\$ 24,841	\$ 26,756	\$ 27,576	\$ 30,733	\$ 40,273	\$ 47,137	\$ 54,616	\$ 59,160	\$ 63,478	\$ 74,506	\$ 89,125	\$ 102,380	\$ 112,144	\$ 125,800
	Medical	\$ 57,724	\$ 63,136	\$ 70,201	\$ 79,448	\$ 84,302	\$ 86,023	\$ 90,033	\$ 94,615	\$ 100,931	\$ 101,955	\$ 118,314	\$ 131,420	\$ 148,823	\$ 176,736	\$ 196,534
Total Life Sciences		\$ 81,143	\$ 87,977	\$ 96,957	\$ 107,024	\$ 115,035	\$ 126,296	\$ 137,170	\$ 149,231	\$ 160,091	\$ 165,433	\$ 192,820	\$ 220,545	\$ 251,203	\$ 288,880	\$ 322,334
Psychology	Psychology	\$ 1,306	\$ 1,570	\$ 1,357	\$ 1,467	\$ 1,928	\$ 2,035	\$ 2,134	\$ 2,180	\$ 1,920	\$ 2,626	\$ 2,937	\$ 3,380	\$ 2,564	\$ 3,050	\$ 2,982
Social Sciences																
	Economics	\$ 1,479	\$ 1,105	\$ 936	\$ 1,566	\$ 1,114	\$ 1,441	\$ 987	\$ 1,078	\$ 1,117	\$ 1,181	\$ 1,086	\$ 1,307	\$ 1,393	\$ 1,238	\$ 1,304
	Political	\$ 227	\$ 158	\$ 311	\$ 370	\$ 486	\$ 386	\$ 158	\$ 128	\$ 120	\$ 144	\$ 57	\$ 9	\$ 1,465	\$ 2,122	\$ 2,737
	Sociology	\$ 1,512	\$ 1,517	\$ 1,106	\$ 425	\$ 664	\$ 1,157	\$ 1,556	\$ 2,324	\$ 1,624	\$ 1,673	\$ 2,420	\$ 2,247	\$ 3,184	\$ 3,249	\$ 3,755
Total Social Sciences		\$ 3,218	\$ 2,780	\$ 2,353	\$ 2,361	\$ 2,264	\$ 2,984	\$ 2,701	\$ 3,530	\$ 2,861	\$ 2,998	\$ 3,563	\$ 3,563	\$ 6,042	\$ 6,609	\$ 7,796
Total Reported		\$ 110,597	\$ 119,527	\$ 128,040	\$ 139,249	\$ 149,311	\$ 160,385	\$ 172,654	\$ 186,001	\$ 200,597	\$ 204,820	\$ 235,579	\$ 264,539	\$ 296,008	\$ 334,317	\$ 373,647
Total Actual			\$ 123,810	\$ 133,747	\$ 144,451								\$ 279,013	\$ 312,434	\$ 351,996	

Source: (NSF d.)

FIGURE D

## CALCULATION OF ISI FOR THE UNIVERSITY OF PENNSYLVANIA

ISI								Percentage	Percentage	Equalized Values		
			1990a	1990a		2000a	2000a	Change in	Change in	for Percent of	Equalized Values	
		1990a	Percent of	Percent of		Percent of	Percent of	Share of	Share of	Institutional	for Change in	ISI
			Institution	National	2000a	Institution	National	National	Institutional	Spending	Share of Spending	
			Spending	Spending		Spending	Spending	Spending	Spending	(IS)	(ΔIS)	
Engineering												
	Aero/Astro	0	0.00	0.00	0	0.00	0.00					
	Chemical	1730	1.34	1.58	1199	0.40	0.61	-61.24	-70.05	0.0079	-0.8994	-0.2972
	Civil	326	0.25	0.29	9	0.00	0.00	-98.66	-98.78	0.0001	-1.2683	-1.2682
	Electrical	1141	0.88	0.27	719	0.24	0.10	-63.28	-72.79	0.0047	-0.9346	-0.3099
	Mechanical	716	0.56	0.31	1353	0.45	0.34	11.99	-18.38	0.0089	-0.2359	-0.0757
	Metal & Mat	2620	2.03	1.86	2545	0.85	1.12	-39.97	-58.03	0.0167	-0.7451	-0.2428
Total Engineering		6533	5.06	0.57	5825	1.95	0.29	-48.62	-61.48			
Physical Sciences												
	Astronomy	0	0.00	0.00	0	0.00	0.00					
	Chemistry	7515	5.83	1.71	10909	3.65	1.72	0.29	-37.28	0.0716	-0.4786	-0.4070
	Physics	6951	5.39	1.08	11257	3.77	1.25	16.46	-30.03	0.0739	-0.3855	-0.3116
Total Physical Sciences		14465	11.21	1.21	22166	7.42	1.24	2.57	-33.79			
Environmental												
	Atmospheric	0	0.00	0.00	0	0.00	0.00					
	Earth/Geol	63	0.05	0.03	95	0.03	0.03	-6.44	-34.85	0.0006	-0.4474	-0.1489
	Ocean	0	0.00	0.00	0	0.00	0.00					
Total Environment		63	0.05	0.01	95	0.03	0.01	-8.30	-34.85			
Mathematics	Mathematics	815	0.63	0.50	999	0.33	0.44	-11.79	-47.00	0.0066	-0.6035	-0.1990
Computer	Computer	5805	4.50	1.68	7453	2.50	1.24	-26.36	-44.53	0.0489	-0.5718	-0.2614
Life Sciences												
	Agriculture	0	0.00	0.00	0	0.00	0.00					
	Biological	26391	20.46	1.43	101216	33.90	2.83	97.37	65.70	0.6645	0.8436	1.5080
	Medical	70928	54.99	2.65	152326	51.02	2.69	1.26	-7.21	1.0000	-0.0926	0.9074
Total Life Sciences		97319	75.44	2.00	253543	84.92	2.58	29.21	12.56			
Psychology	Psychology	1465	1.14	0.87	2998	1.00	0.85	-2.64	-11.56	0.0197	-0.1485	-0.0644
Social Sciences												
	Economics	1202	0.93	2.14	1313	0.44	1.46	-31.71	-52.83	0.0086	-0.6783	-0.2232
	Political	310	0.24	1.17	1278	0.43	2.03	74.06	77.89	0.0084	1.0000	0.3361
	Sociology	1016	0.79	1.64	2893	0.97	2.13	30.08	23.04	0.0190	0.2958	0.1049
Total Social Science		2529	1.96	1.75	5484	1.84	1.90	8.84	-6.30			
Total Reported		128994	100.00	1.49	298563	100.00	1.86	24.47				
Total Actual		134003			314481							
Percent Reported		96.26			94.94							
Percent change in reporting					-1.38							

**FIGURE E**

STRATEGIC PORTFOLIO ARRAY FOR THE UNIVERSITY OF PENNSYLVANIA

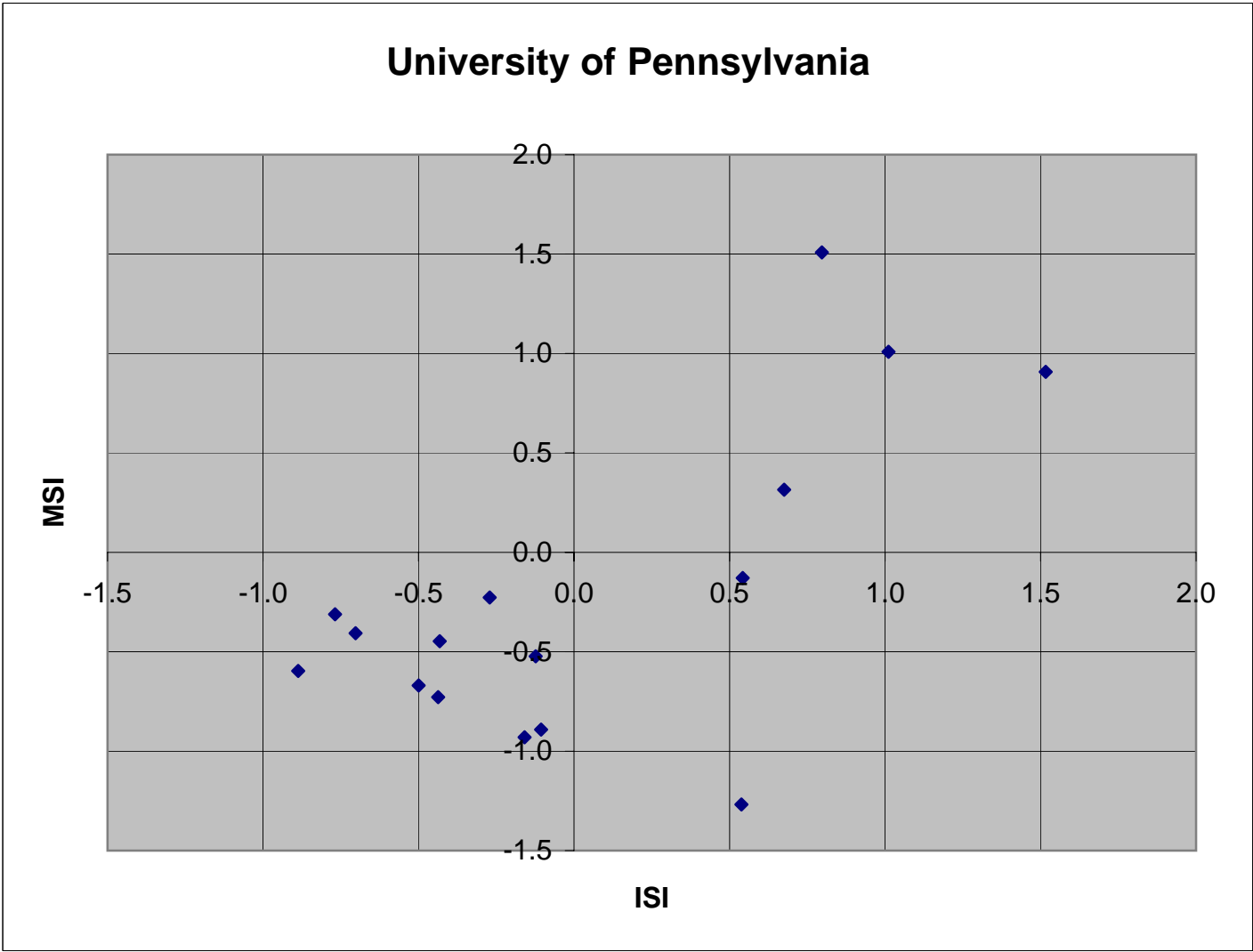


FIGURE F

## THE RESULTS

	$\Delta MS$	# fields	UNWEIGHTED				SW	Max Spread	SW+NE	NW+SE	(SW+NE)-(NW+SE)
			# NW	# NE	# SW	# SE	/# fields	/# fields	/# fields	/# fields	/# fields
Northwestern	36.78	15	3	3	8	1	0.53	0.47	0.73	0.27	0.47
U of Colorado	34.35	19	3	4	11	1	0.58	0.53	0.79	0.21	0.58
U of Missouri	31.74	16	1	4	8	3	0.50	0.44	0.75	0.25	0.50
Washington U	29.31	16	2	4	9	1	0.56	0.50	0.81	0.19	0.63
U of Pennsyl	24.47	16	0	4	10	2	0.63	0.63	0.88	0.13	0.75
U of Arizona	21.57	19	2	5	8	4	0.42	0.32	0.68	0.32	0.37
Cal Tech	15.43	13	0	3	6	4	0.46	0.46	0.69	0.31	0.38
Case Western	13.33	14	3	3	8	0	0.57	0.57	0.79	0.21	0.57
U of Florida	12.37	20	4	3	10	3	0.50	0.35	0.65	0.35	0.30
U of Virginia	11.30	18	3	4	11	0	0.61	0.61	0.83	0.17	0.67
U of N. Carolina	11.20	11	0	4	6	1	0.55	0.55	0.91	0.09	0.82
U of Maryland	6.54	18	1	4	3	10	0.17	0.50	0.39	0.61	-0.22
Vanderbilt	3.15	16	3	3	7	3	0.44	0.25	0.63	0.38	0.25
Duke	2.89	15	3	3	7	2	0.47	0.33	0.67	0.33	0.33
Rutgers	0.78	18	3	3	4	8	0.22	0.28	0.39	0.61	-0.22
Harvard	0.41	11	3	3	4	1	0.36	0.27	0.64	0.36	0.27
Indiana	-0.36	12	1	5	6	0	0.50	0.50	0.92	0.08	0.83
Michigan State	-3.54	11	1	4	4	2	0.36	0.27	0.73	0.27	0.45
U of Michigan	-3.56	19	5	2	10	2	0.53	0.42	0.63	0.37	0.26
Ohio State	-3.85	19	4	3	10	2	0.53	0.42	0.68	0.32	0.37
U of Minnesota	-4.74	18	5	2	8	3	0.44	0.33	0.56	0.44	0.11
UCLA	-5.35	18	4	3	9	2	0.50	0.39	0.67	0.33	0.33
USC	-7.35	19	5	2	9	3	0.47	0.37	0.58	0.42	0.16
U of Iowa	-7.93	16	4	3	7	2	0.44	0.31	0.63	0.38	0.25
Columbia	-9.24	17	4	3	8	2	0.47	0.35	0.65	0.35	0.29
UC San Diego	-11.85	13	3	3	6	1	0.46	0.38	0.69	0.31	0.38
Stanford	-12.64	18	5	1	9	3	0.50	0.44	0.56	0.44	0.11
Yale	-12.89	17	2	3	9	3	0.53	0.41	0.71	0.29	0.41
U of Chicago	-15.22	12	2	4	6	0	0.50	0.50	0.83	0.17	0.67
UC Berkeley	-15.78	16	4	3	4	5	0.25	0.13	0.44	0.56	-0.13
U of Wisconsin	-17.34	20	3	4	12	1	0.60	0.55	0.80	0.20	0.60
U of Rochester	-22.19	14	1	4	6	3	0.43	0.36	0.71	0.29	0.43
Purdue	-22.29	18	2	3	7	6	0.39	0.28	0.56	0.44	0.11
New York	-25.40	11	0	5	0	6	0.00	0.55	0.45	0.55	-0.09
Cornell	-25.58	18	3	3	9	3	0.50	0.33	0.67	0.33	0.33
Johns Hopkins	-25.92	20	2	5	10	3	0.50	0.40	0.75	0.25	0.50
Princeton	-27.57	16	2	4	5	5	0.31	0.19	0.56	0.44	0.13
Carnegie Melon	-29.16	13	3	1	5	4	0.38	0.31	0.46	0.54	-0.08
MIT	-34.67	18	3	2	6	7	0.33	0.28	0.44	0.56	-0.11
Correlation to $\Delta MS$			-0.16	0.23	0.29	-0.32	0.41	0.44	0.46	-0.46	0.46
Total # of Fields		628	102	129	285	112					
Mean # of Fields		16.10	2.62	3.31	7.31	2.87					